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The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
The objective of this research is to explore how optimization can be used to explore locate military assets on a network and dispatch the assets to spatially-located and prioritized calls for service. To meet this objective, we formulate new discrete optimization models and algorithms that provide new capabilities for military transportation systems by exploring new models and algorithms for making integrated resource allocation decisions. This research has direct application to locating and dispatching military aeromedical evacuation systems (medevacs). The key contribution of this approach is that it provides an important step toward integrating complex military transportation

15. SUBJECT TERMS
discrete optimization,Markov decision processes, networks, MEDEVACS, soldier survivability

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a. REPORT	b. ABSTRACT	c. THIS PAGE			Laura McLay
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Report Title

Final Report: Optimally Managing Dynamic Military Server-to-Customer Systems

ABSTRACT

The objective of this research is to explore how optimization can be used to explore locate military assets on a network and dispatch the assets to spatially-located and prioritized calls for service. To meet this objective, we formulate new discrete optimization models and algorithms that provide new capabilities for military transportation systems by exploring new models and algorithms for making integrated resource allocation decisions. This research has direct application to locating and dispatching military aeromedical evacuation systems (medevacs). The key contribution of this approach is that it provides an important step toward integrating complex military transportation systems for improving survivability by explicitly focusing on survival by investigating two interrelated, traditional problems, namely, how to locate and dispatch servers.

This project's novelty lies in including five important features in the modeling framework that have not been considered in combination in the literature. In particular, this research: (1) explores new modeling paradigms that explicitly link soldier casualties (i.e., survivability) to resource allocation decisions; (2) considers multiple types of assets rather than a fleet of indistinguishable assets; (3) allows for geography-dependent parameters (e.g., travel times); (4) prioritizes potential customers by need; and (5) balances multiple criteria such as effectiveness with vulnerability.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received	Paper
08/07/2014 11.00	Laura A. McLay, Maria E. Mayorga. A model for optimally dispatching ambulances to emergency calls with classification errors in patient priorities, IIE Transactions, (01 2013): 1. doi: 10.1080/0740817X.2012.665200
08/07/2014 12.00	Laura A. McLay, Maria E. Mayorga. A Dispatching Model for Server-to-Customer Systems That Balances Efficiency and Equity, Manufacturing & Service Operations Management, (05 2013): 205. doi: 10.1287/msom.1120.0411
TOTAL:	**2**

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper
TOTAL:	

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received		Paper
01/31/2011	1.00	L. McLay. A mixed-integer programming model for enforcing priority list policies in Markov decision process models, (01 2011)
08/20/2011	3.00	Laura A. McLay, Maria E. Mayorga. A model for optimally dispatching ambulances to emergency calls with classification errors in patient priorities, Working Paper (08 2011)
09/19/2012	8.00	L. McLay. A mixed-integer programming model for enforcing priority list policies in a Markov decision process model, ( )
TOTAL:		**3**

Number of Manuscripts:

Books

Received	Book
TOTAL:	

Received	Book Chapter
TOTAL:	

Patents Submitted

Patents Awarded

Awards

ARO Young Investigator Award for the research project entitled “Optimally Managing Dynamic Military Server-to-Customer Systems" (May 2010 – May 2013).

Excellence in Scholarship Award, College of Humanities and Sciences, Virginia Commonwealth University, 2012. This award is a college-wide award for research excellence across all ranks of professors.

Laura McLay was appointed as an Associate Professor of Industrial & Systems Engineering at the University of Wisconsin-Madison in May 2013.

Best Paper Award for IIE Transactions Focused Issue on Scheduling and Logistics for the paper entitled “A model for optimally dispatching ambulances to emergency calls with classification errors in patient priorities.”

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Benjamin Grannan	0.25	
Philip Leclerc	0.05	
FTE Equivalent:	**0.30**	
Total Number:	**2**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Laura McLay	0.20	No
FTE Equivalent:	**0.20**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Benjamin Grannan
Total Number: 1

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Significance

The contribution of the research is to extend an important class of optimization problems for allocating resources on a network. From the theoretical point of view, the models provide novel formulations for managing limited military transportation assets that address several important features. From the computational point of view, the new discrete optimization models can leverage powerful computational tools and advanced algorithms. The model solutions will be interpreted to provide simple guidelines that can be used to optimally manage limited medevac resources in the theater of operations. These contributions to basic science can enable improvements in military systems by providing fundamental insights into how the optimal policies for managing scarce transportation assets can improve soldier outcomes. More specifically, this project takes an important step toward transforming military medevacs from delivering limited resources in a fixed timeframe (e.g., transporting soldiers in two hours) to explicitly focusing on survival by investigating the two interrelated problems of locating and dispatching medevacs. The potential applications of this research project are broad, since the results can be applied to other military logistics problems in which time-sensitive commodities must be delivered to prioritized calls for service with limited resources.

Accomplishments in the current grant

This research project is composed of smaller projects, many of which have led or are leading to publications in peer-reviewed journals (six papers to date, plus more in process). The completed research has been summarized in detail in peer-reviewed journal publications (see Section X). The ongoing research will be published in the future. Here, I briefly outline the accomplishments.

A. A dispatching model for dispatching heterogeneous assets to prioritized and spatially-located casualties with prioritization errors. This model was later extended to allow for the consideration of multiple objectives. These papers examine the need to consider prioritization in making resource allocation decisions. They illustrate the importance of informational accuracy in the decision-making process.
B. An efficient dispatching model for finding optimal policies that conform to simple dispatching rules that can aid in decision-making in the theater of military operations. The model formulation is novel, and it is more scalable than traditional approaches, which allows for the use of standard integer programming algorithms.
C. A discrete optimization model and algorithm for jointly locating and dispatching assets on a network where calls for service arise. The optimization model utilizes a queuing model that captures the dynamics of calls arriving to the system.
D. A model that seeks to dispatch and transport casualties in a network. This model is used to examine how the revelation of information for each call affects resource allocation decisions when resource allocations made with the initial, imperfect information is acquired later constrain decisions that can be made when more accurate information is acquired.
E. Cross-utilization of workers whose capabilities differ using the bio-inspired model of the generalized matching law that informs an optimization model, thus integrating optimization and behavioral methodologies in a new way.
F. An optimization model for locating and dispatching two types of assets to prioritized casualties. This model focuses on dispatching heterogeneous types of assets to prioritized casualties, where there are restrictions on the types of assets that can be allocated to different types of casualties. This paper lifts two assumptions: that there is a fleet composed of a single type of vehicle and any vehicle can respond to any type of casualty. One contribution is a new spatial queuing model to compute asset busy probabilities and dispatch probabilities that capture the system dynamics in a system with two types of assets. Another contribution is a new iterative algorithm solve the optimization models with spatial queuing inputs.

Current research projects are as follows:

G. An optimization model for dispatching heterogeneous types of assets to prioritized casualties and that allows for multiple assets to respond to customers. This paper lifts the assumption that only one asset responds to each call for service. This project necessitates algorithms to both (a) support spatial queuing models that capture the system dynamics and (b) solve the optimization models.

Technology Transfer

I met with Mr. Jack Zeto, Ms. Debbie Lott, and Col. Wade Yamada at Fort Belvoir on February 22, 2012 to discuss research developments. At that time, I gave a short presentation on some of the research findings and future research directions. I have been in contact with Mr. Jack Zeto and Col. Wade Yamada since 2009. Feedback from Mr. Jack Zeto has been invaluable for improving and refining models that we have explored throughout this project.

A notable collaboration is with LTC Nathaniel Bastian, who is currently a PhD student at Penn State University. LTC Bastian has provided feedback to some of our models and is a coauthor on one of our papers under review.

Technology Transfer Outreach: I presented the following papers at conferences sponsored by the Army:

- Talk given on October 19-21, 2011 at the Army Conference on Applied Statistics in Annapolis, MD: “A mixed-integer programming model for enforcing priority list policies in Markov decision process models.”
- Talk given on October 24-26, 2012 at the Army Conference on Applied Statistics in Monterey, CA: “A mixed integer programming model for locating and dispatching ambulances,” Army Conference on Applied Statistics.